GCA TECHNICAL REPORT NO. 63-14-N

NASA CR 52165

38p.

N64 10086

CODE-1

OTS PRICE

XEROX $ 3.60 ph

MICROFILM $ 1.34 mf.

A ROCKET-BORNE 44-60 Å GEIGER COUNTER

C. A. ACCARDO H. G. GROSS L. H. WEEKS

CONRACT NO. NASw-500

PREPARED FOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON 25, D. C.

MAY 1963

GEOPHYSICS CORPORATION OF AMERICA BEDFORD, MASSACHUSETTS

GCA-Technical Report No. 63-14-N TR- OTS: $3.60 ph, $1.34 mf.

A ROCKET-BORNE 44 - 60 Å GEIGER COUNTER

C. A. Accardo,
H. G. Gross, and
L. H. Weeks

May 1963 38 p 10 refs

NASA Contract No. NASw-500

GEOPHYSICS CORPORATION OF AMERICA
Bedford, Massachusetts

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington 25, D. C.

TABLE OF CONTENTS

ABSTRACT

/0086

The report constitutes the preliminary work in the design and construction of a 44 - 60Å Geiger counter for use in sounding rockets. The counter response as a function of orientation with respect to the sun is investigated both theoretically and experimentally. The counter will be included in seven Nike-Apache payloads to be flown during the solar eclipse of July 20, 1963, for studying the ionosphere. AUTHOR

SECTION 1

INTRODUCTION

The use of Geiger counters to study the extreme ultraviolet and X-ray emission from the sun has been extensively investigated particularly at NRL over the past decade. Apart from obtaining information of solar processes these studies also serve to establish the intimate relationship between the upper atmosphere and solar influences. For example, there is a great deal of evidence correlating certain ionospheric disturbances with enhanced emission in the X-ray region (2-8 Å). Also more recent theories together with experimental data point to soft X-rays as an important source of ionization for the D and E region ionosphere.

To date there have been no simultaneous measurements made of electron density and solar intensity in the ionosphere. The use of sounding rockets with Langmuir probes to measure electron density as well as solar detectors sensitive to the pertinent wavelength bands, allows "in situ" measurements and a unique cross-correlation of data to be made. In addition, the occurrence of a solar eclipse allows the effects of a known time varying source of ionization to be studied by these probes. To this end a soft X-ray Geiger counter has been constructed and will be included in the July 20, 1963 eclipse measurements at Ft. Churchill, Canada.

The Geiger counter has been designed to cover the 44 to 60 Å spectral range. Its theory of operation, construction and general characteristics are discussed. In addition, the effect of rocket orientation with respect to the sun on counter efficiency and wavelength response is investigated theoretically and experimentally.

Two control rocket flights have served to assess the usefulness of these Geiger counters for quantitative measurements in the ionosphere during the Ft. Churchill eclipse.

SECTION 2

GENERAL THEORY OF COUNTER

The operation of a Geiger counter is dependent upon the incident radiation producing at least a single ion pair within the sensitive volume of the counter. This will in general be a function of many parameters including the type of radiation (quantum or corpuscular), the energy of the radiation, the wall thickness of the counter, gas filling, etc. Subsequent to the production of the ion pair, the electron is accelerated to the anode (usually a tungsten or nickel wire of several mils diameter). As the electrons approach this region of high electric field strength in the vicinity of the center wire, they obtain enough energy to further ionize the gas in the counter by collisions. This process results in a Townsend avalanche along the wire and gives rise to an electrical pulse capable of being detected in either the anode or cathode of the counter. A trace amount of quenching gas is used with the primary counter gas to prevent spurious pulses from being produced.

The operating voltage of the counter is usually found by plotting the count rate as a function of the applied voltage for a constant intensity source located at some fixed distance from the counter. To avoid correcting for the pulses occurring during the dead time, a low rate is usually selected for this measurement (~ 100c/sec). Depending on various parameters such as positioning of the fine anode wire, the nature of the plateau (region of linearity) may differ. The operating voltage is normally selected near the center of the plateau.

The radiation to be measured is admitted to the counter through a thin window which is partially transparent to these wavelengths. The efficiency of the counter is given by the product of the transmissivity of the window and the photoionization of the gas:

$$\epsilon(\lambda) = e^{-[\mu/\rho(\rho r)]_W} \left\{1 - e^{-[\mu/\rho(\rho r)]_G}\right\} ,$$

where μ/ρ is the mass absorption coefficient, ρ is the density, r is the distance traversed by the radiation, and W and G designate those terms pertaining to the window and gas respectively. For the wavelengths of interest, mylar has proven successful as a window, allowing the wavelengths 44-60 Å and 2-20 Å to be transmitted. The high energy cutoff at 43.6 Å is determined by the K edge of carbon (principal constituent of mylar), and the transmissivity at lower energies falls off approximately as the inverse cube of the wavelength. The primary gas used is neon, which has a very high mass absorption coefficient at the higher wavelength window and drops with increasing energy. This is mixed with 1.15% isobutane which serves as the quenching agent. For a 1/4 mil mylar window thickness and gas pressures of one-half to one atmosphere, the normal counter efficiency at 44-60 Å is a few percent. Although the efficiency is higher than this in the 2-20 Å band, the relative response is much less during quiet solar conditions because the total energy in that interval is much less than in the 44-60 Å interval.

SECTION 3

CONSTRUCTION OF GEIGER COUNTER

A photograph of the design used is shown in Figure 1. The Geiger counter is a rugged side-window type, self-quenched, with metal envelope and window support constituting the cathode, and ceramic-metal feed-throughs for support of the central anode wire. A metal exhaust-gas fill tubulation is centrally located in the side of the envelope. The tubes are filled to a given pressure and pinched off.

There are two support legs for attachment of the counter to a base support plate, which is mounted in the rocket payload frame. The window support is so attached to the envelope that it makes an angle of 30° between the window surface and the base support plate, permitting a particular viewing angle from the side of the rocket as discussed in Section V.

Inherent to the design is considerable flexibility in use of window materials, gas-fills, angles of orientation and cathode and anode materials. For the particular application here, to radiation

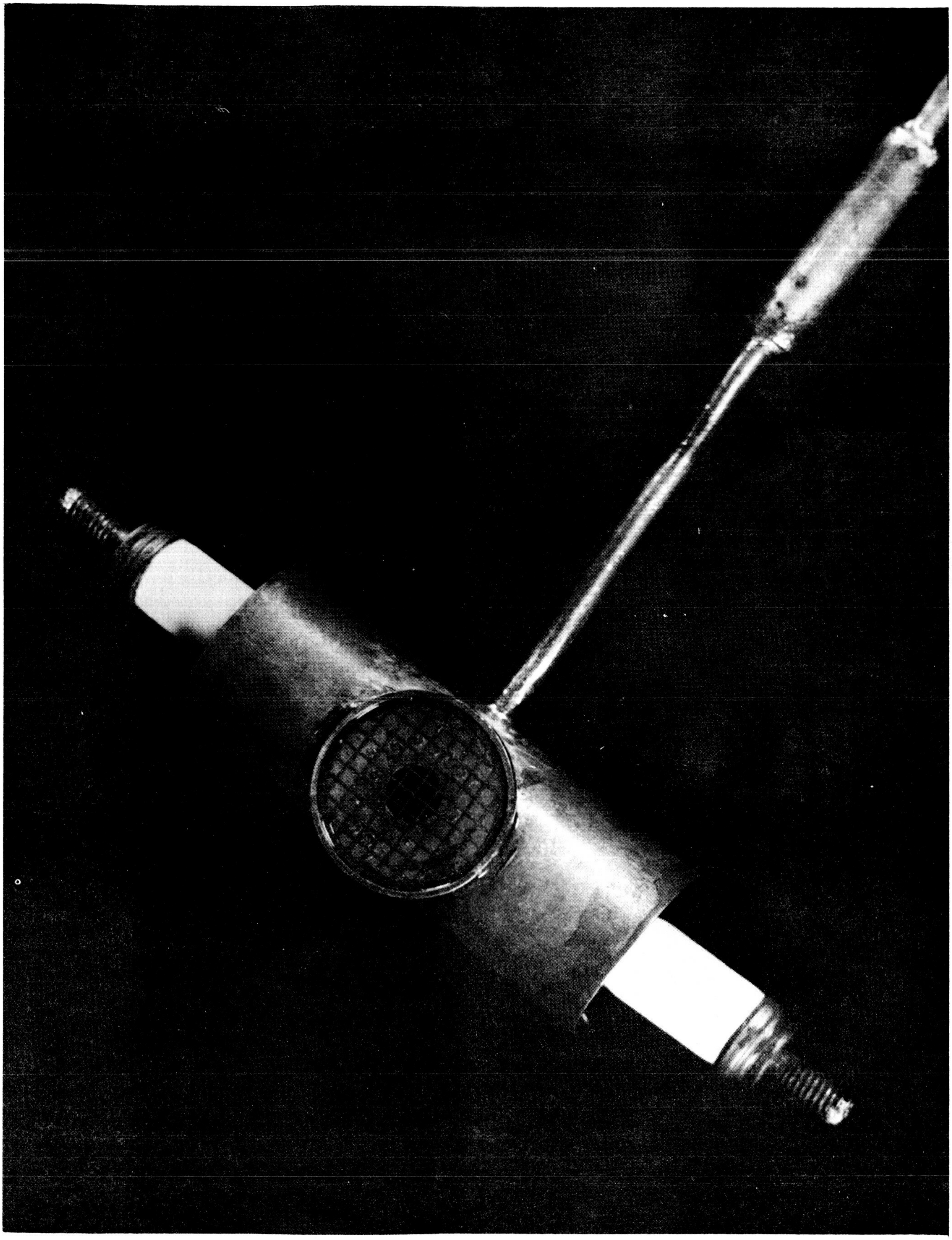


Figure 1. Geiger counter.

in the range of 44-60Å, a very thin mylar window (0.00025 in.) is attached to the window support base by a special technique. The aperture is a hole of 1/4 inch diameter, but is easily changed to any practical size.

The mylar window has the option of being attached (1) by itself, (2) sandwiched between two tungsten support meshes, or (3) under a washer-type disc. As laboratory tests and actual flights have shown, the mylar window is capable of withstanding the rigors of launch and flight without additional supports. It also can survive several cycles of inward and outward protrusion at the aperture at various stages of fabrication and testing due to a gas pressure differential of 1 atmosphere. In the initial flight, the counter was flown without any mesh or disc. In the second flight a tungsten mesh was used to support the mylar window.

The gas-fill, as discussed earlier, is neon with 1.15% isobutane as the quenching agent. The counter is normally filled with a pressure of slightly over 1 atmosphere to keep the thin window protruding outward at all times, even at ground level, thus avoiding unnecessary inward-outward flexures that might weaken it. Operationally, the counter performs as well as 1/2 atmosphere of gas-fill also.

Conventional painstaking tube techniques in the cleaning and preparation of all parts of the counter are applied to ensure the optimum in operating characteristics and performance. The envelope and window support are of brass, machined internally to a high finish, electro-polished, and gold plated to minimize all undesirable emission from the surfaces, chemical reactions, and corrosion. The ceramic-metal feed-throughs are soldered with the window support to the envelope. The anode is a tungsten wire (0.005 in. diameter) carefully cleaned, glowed (resistance heated by passing current through it in partial vacuum), and soldered under tension to the ceramic-metal feed-throughs along the central axis of the tube. The clamped-clamped mode of attachment of the anode wire under tension thus minimizes large displacement amplitudes that might occur under rocket shock and vibration. The total length of the counter is 4 1/2 inches, the envelope length being 2 1/4 inches and the outer diameter 7/8 inches.

Testing includes both mechanical and electrical phases. Besides establishing the basic operational characteristics of each Geiger counter electrically, thereby making possible the selection of the best counters and optimum operating parameters for each, these counters are in turn placed under a vacuum of 10^{-6} torr. several times to test window strength and adhesion. Electrical characteristics are checked again after each exposure to a high vacuum environment.

The typical operating conditions and characteristics of this counter are as follows:

Operating Voltage	approx. 1000 volts
Starting Voltage	approx. 800 volts
Dead Time	approx. 80 μsec
Max. Counting Rate	approx. 4000 counts/sec — 12,500 counts/sec
Pulse Amplitude (across 1 meg. resistor)	approx. 1 volt

The design discussed here is similar to counters used by NRL in their investigations of solar radiation. Valuable discussions with members of the staff at NRL together with certain vendors who provided NRL with counter envelopes were of inestimable value in the design and fabrication of the Geiger counter.

SECTION 4

ROCKET INTEGRATION

The position of the Geiger counter within the rocket is shown in Figure 2. The counter is located within a package containing two Lyman α counters and an aspect angle sensor. The high voltage power supply (850 - 1500 volts) and electronics for the counter are situated directly above the counter. In order to achieve a better impedance match with the counting circuit as well as isolating the circuit from the high voltage side, the pulses are detected in the cathode loop of the counter through a 100 K resistor. The pulses are fed to a completely transistorized module utilizing only 2N338A transistors. The first stages constitute a saturated amplifier triggered by pulses above 50 mv. The output of the amplifier triggers a "one-shot" which produces a 25 μsec square wave of 8 volts amplitude across a 150 ohm output. These pulses will AM modulate the transmitter carrier (231.4 Mc). A schematic of the circuit is shown in Figure 3.

The decoding of the telemetry data is achieved by a count rate circuit which samples the records in millisecond intervals and

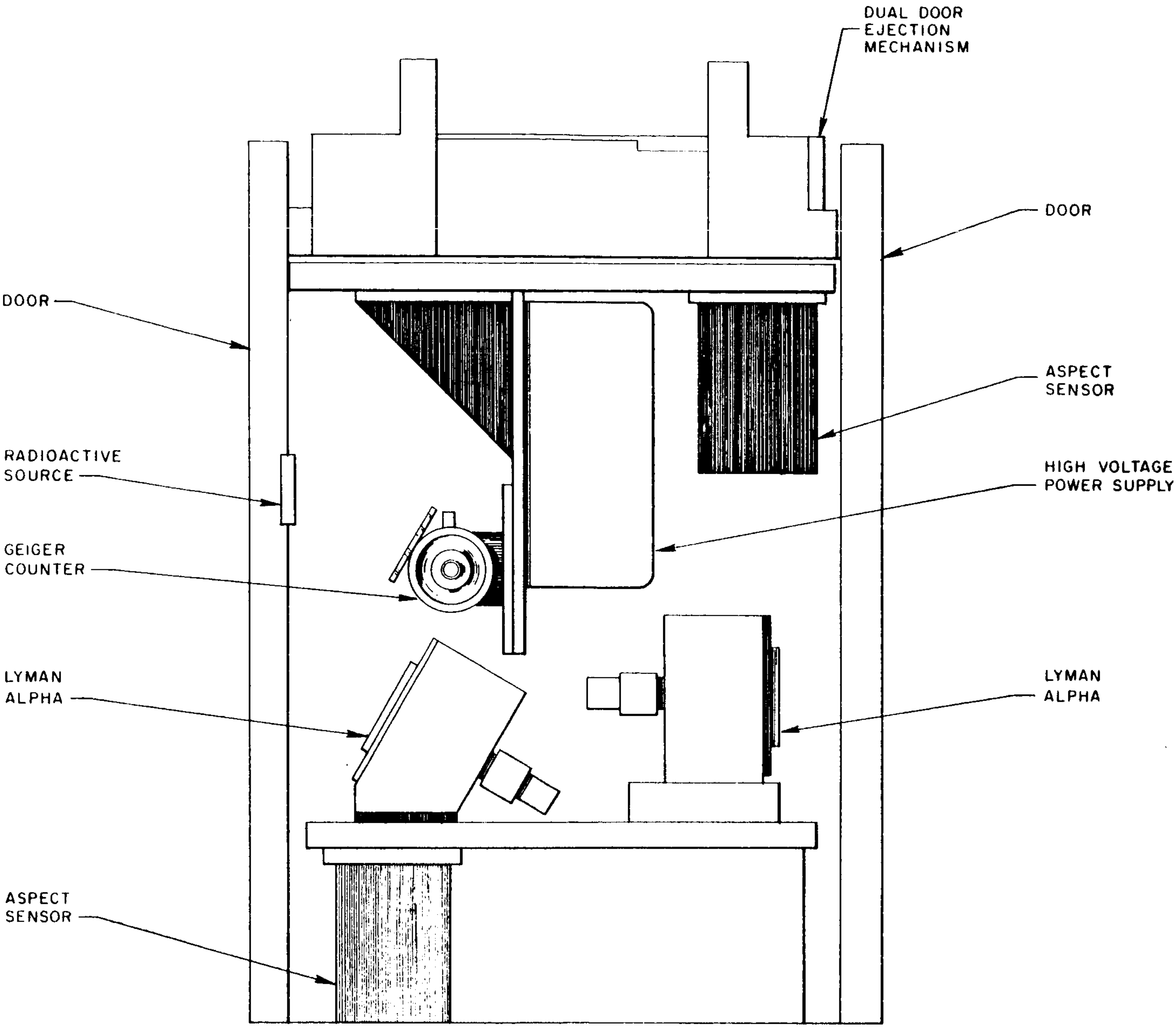
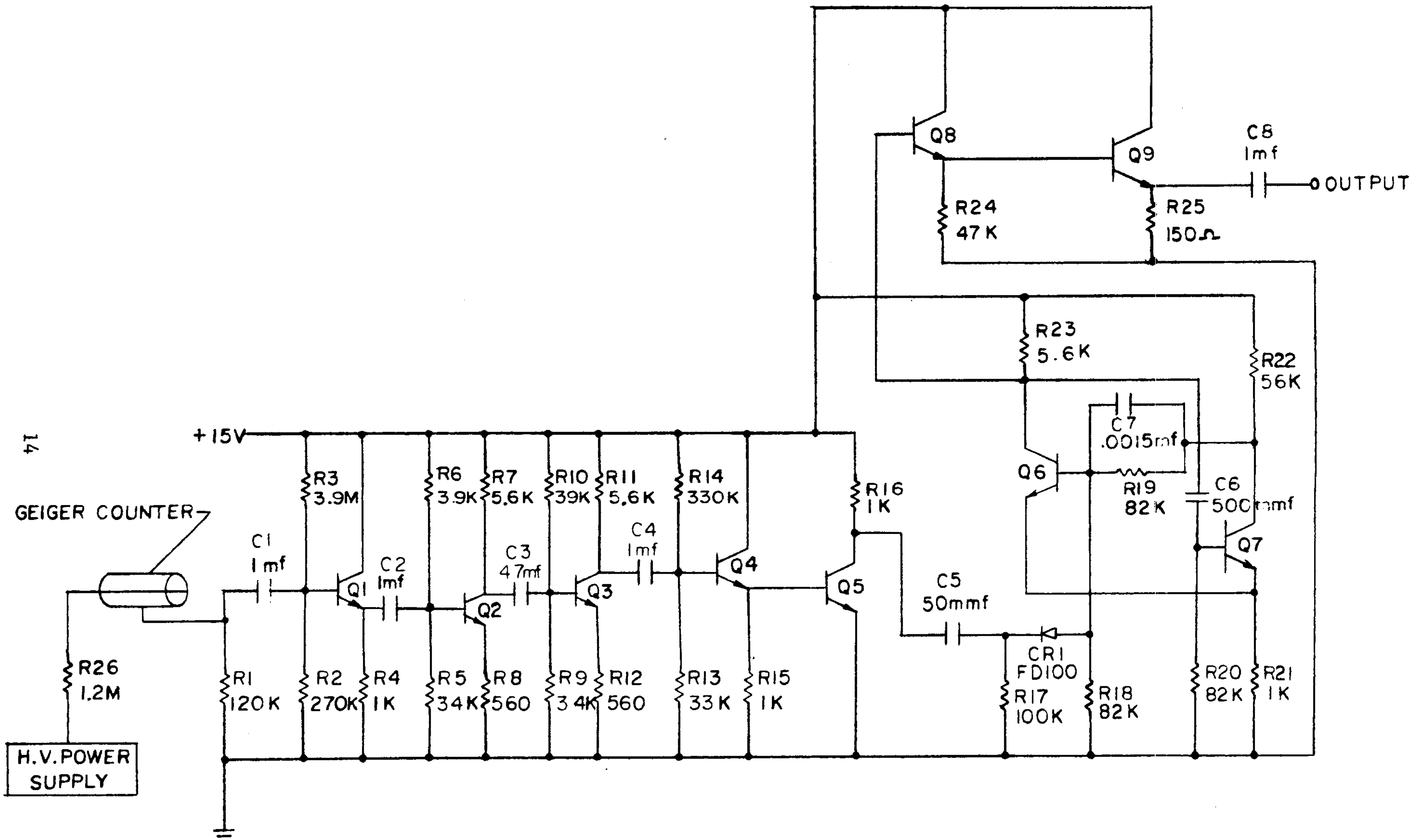


Figure 2. Position of Geiger counter and other equipment within payload.



GEIGER COUNTER ELECTRONICS FOR NIKE-APACHE

Figure 3.

produces an analogue voltage output which by prior calibration is related to the rate of pulses occurring within the sampling interval. For rates much lower than 1000 counts per second this circuit becomes a single pulse counter.

So that the counter may be monitored from launch, a weak radioactive source of Co^{60} is attached to a panel which is released at approximately 150,000 ft. This source provides a fixed count rate of 8c/sec.

SECTION 5

EFFECT OF ROCKET ORIENTATION ON THE DETECTION OF SOLAR RADIATION

The direction cosines of the Geiger counter window with respect to the sun, α and β, are related to the rocket position. The aspect angle of the rocket, α_r, is the angle between the sun-rocket line and the normal to the rocket which is contained in the plane defined by the sun-rocket line and the longitudinal axis of the rocket. The rocket azimuth angle, β_r, is the angle that a normal to a surface element (projection of detector) makes with the normal to the spin axis which is in the plane of the spin axis and the sun-rocket line. These angles are shown in Figure 4. In order that the counter be in the most favorable position with respect to the sun during the July 1963 eclipse, it is mounted on the rocket such that its window normal makes an angle of 30° with respect to that normal to the spin axis having the same azimuth position as seen in Figure 2. It follows

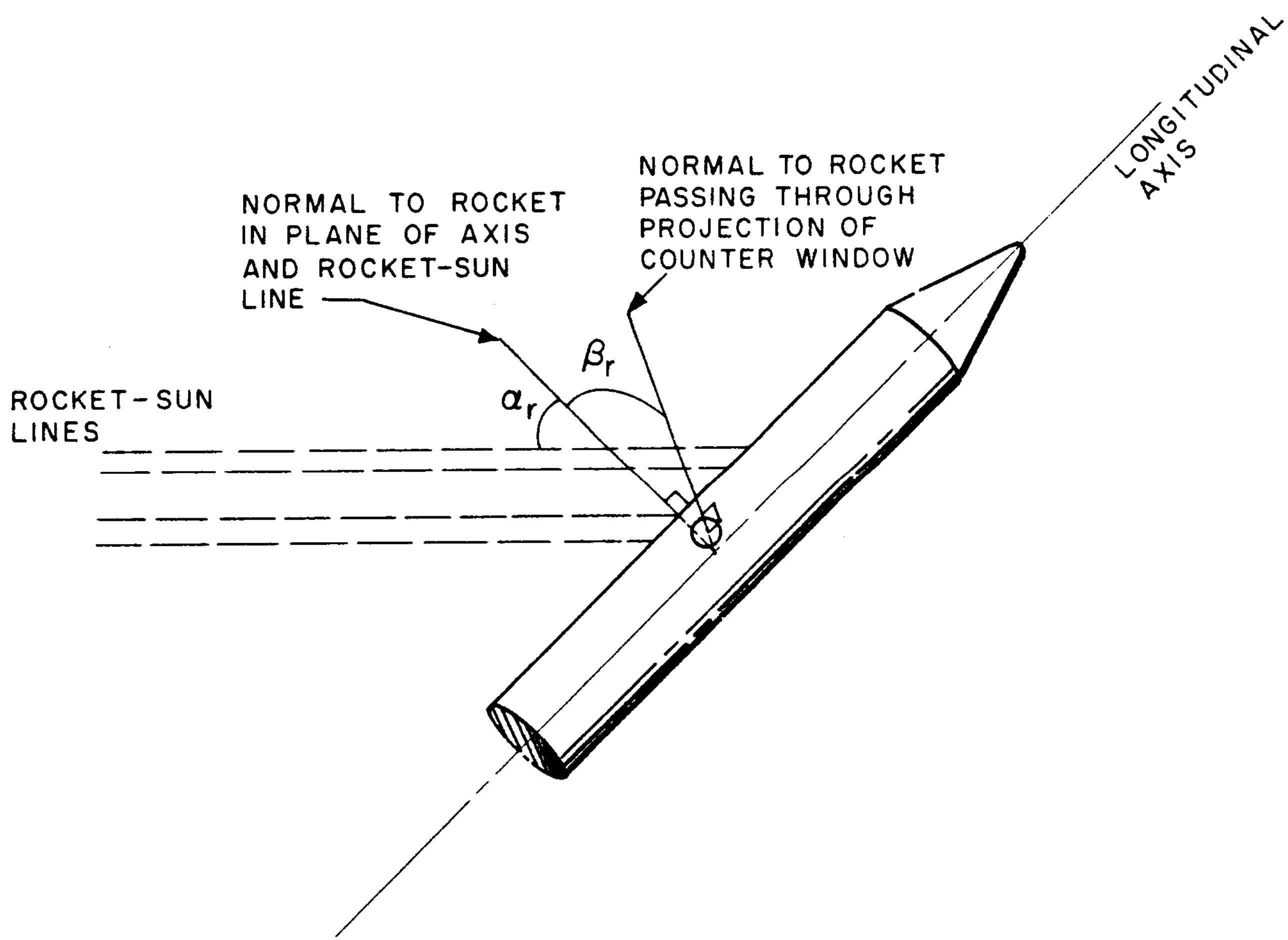


Figure 4. Rocket aspect and azimuth angles.

that

$$\alpha = \alpha_r - 30^o$$

and

$$\beta = \beta_r \ .$$

Thus α and β may be found directly from the rocket aspect and azimuth measuring instruments. The physical position of the counter limits the view of the sun for α up to 35^o on one side and for β up to 18^o on either side.

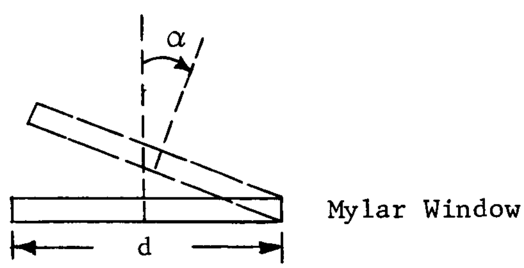
5.1 EFFECT OF REDUCED FLUX

With the Geiger counter directly facing the sun (normal incidence), the amount of flux incident on the mylar window is given by

$$I_o = \frac{\pi d^2}{4} \varphi ,$$

where d is the diameter of the mylar window and φ is the flux density of solar radiation.

Now suppose the counter is tilted by an angle α with the sun's rays



The effective area of the window is its projection in the solar direction which is

$$\frac{\pi}{4} d \ (d \cos \alpha)$$

If, in addition, the detector is tilted by an angle β in the perpendicular plane, the effective area is

$$\frac{\pi}{4} (d \cos \beta) (d \cos \alpha) \quad .$$

The total incident flux with direction cosines α and β with respect to the normal to the window is therefore

$$I (\alpha, \beta) = \frac{\pi d^2}{4} \varphi \cos \alpha \cos \beta \quad .$$

Thus, the incident flux is reduced by a factor

$$R_F = \cos \alpha \cos \beta$$

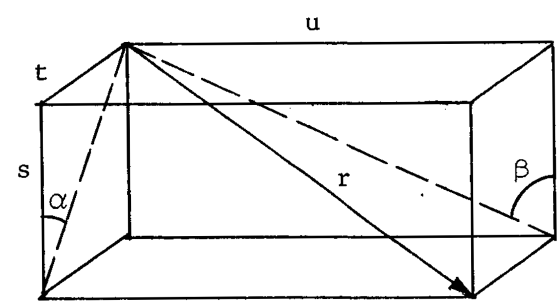
due to the decreased projected area of the window.

5.2 EFFECT OF MYLAR WINDOW

Consider monochromatic radiation of wavelength λ and direction cosines α and β to a surface having a uniform thickness s and absorption coefficient μ. The transmitted intensity is given by

$$I (\alpha, \beta) = I_o e^{-\mu r (\alpha, \beta)}$$

where r is the path length within the surface.



From the figure,

$$r^2 = s^2 + t^2 + u^2, \text{ where}$$

$$t = s \tan \alpha \text{ and } u = s \tan \beta \quad .$$

Then

$$r = s\sqrt{1 + \tan^2 \alpha + \tan^2 \beta} \; ,$$

so that

$$I(\alpha, \beta) = I_o \, e^{-\mu s \sqrt{\sec^2 \alpha + \tan^2 \beta}} \; ,$$

and the ratio of transmitted intensities at oblique incidence to normal incidence, due to an increased path within the mylar window, is

$$R_W = e^{-\mu s \sqrt{\sec^2 \alpha + \tan^2 \beta} - 1} \; .$$

Passing over to the case of a continuous distribution of radiation in a wavelength range $\Delta\lambda$, we have

$$R_W = \frac{\int_{\Delta\lambda} I_o(\lambda) \; e^{-\mu(\lambda) s \sqrt{\sec^2 \alpha + \tan^2 \beta}} \, d\lambda}{\int_{\Delta\lambda} I_o(\lambda) \; e^{-\mu(\lambda) s} \, d\lambda}$$

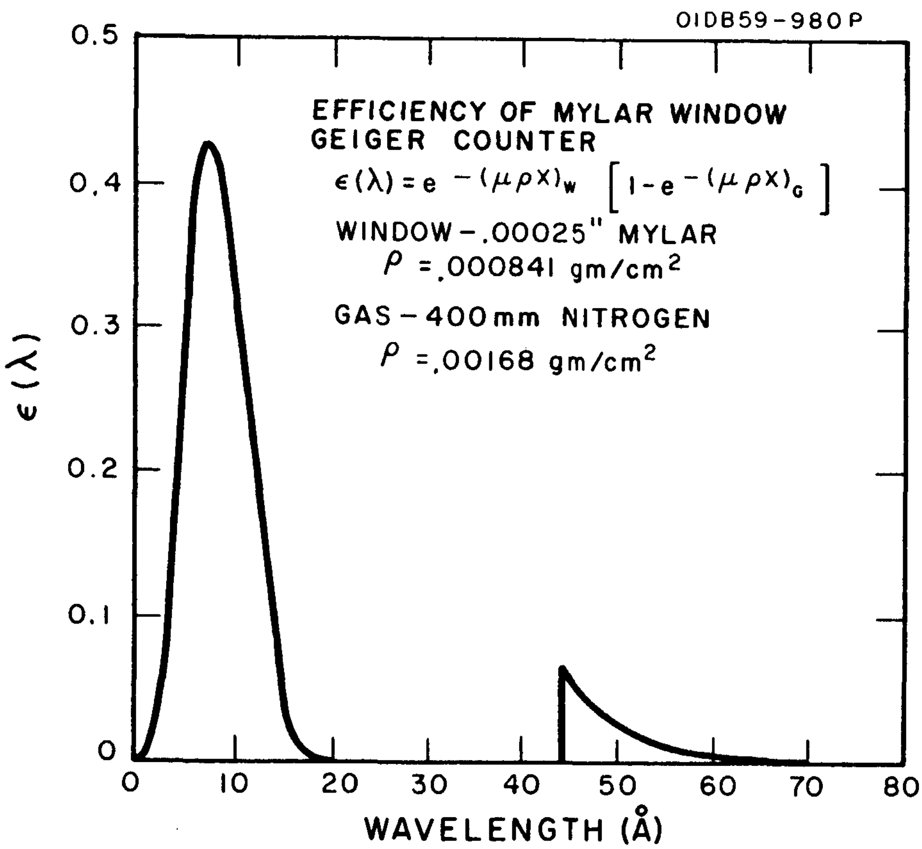
where

$I_o(\lambda) d\lambda$ is the total flux between λ and $\lambda + d\lambda$. If $I_o(\lambda)$ is almost constant in this wavelength range,

$$R_W = \frac{\int_{\Delta\lambda} m(\lambda)^{\gamma} \, d\lambda}{\int_{\Delta\lambda} m(\lambda) \, d\lambda}$$

where $m(\lambda) = e^{-\mu(\lambda) s}$ and $\gamma = \sqrt{\sec^2 \alpha + \tan^2 \beta}$.

The over-all efficiency of a mylar window ion chamber used by Kreplin is shown in Figure 5. The wavelength dependence of



01DB59-980P
EFFICIENCY OF MYLAR WINDOW
GEIGER COUNTER
$\epsilon(\lambda) = e^{-(\mu \rho x)_W} \left[1 - e^{-(\mu \rho x)_G} \right]$
WINDOW - .00025" MYLAR
ρ = .000841 gm/cm^2
GAS - 400mm NITROGEN
ρ = .00168 gm/cm^2
$\epsilon(\lambda)$
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60
70
80
WAVELENGTH (Å)

Figure 5.

the efficiency over the band pass from 43.6 Å to 60 Å is due essentially to the mylar since the photoionization efficiency of the gas (nitrogen) at these wavelengths is practically 100%. A numerical integration of the efficiency curve in Figure 5 yields

$$\int_{43.6\ \text{Å}}^{60\ \text{Å}} m(\lambda)\ d\lambda = .37\ \text{Å}$$

or an over-all efficiency ϵ_o at normal incidence of 2.25%. Since $m(\lambda)$ may be approximated by

$$m(\lambda) = 82.8\ e^{-.164\lambda}$$

the numerator of R_W may be integrated, giving

$$R_W = \frac{16.5}{\gamma}\left[\, e^{-2.73\gamma} - e^{-5.42\gamma} \right].$$

This correction factor is plotted in Figure 6.

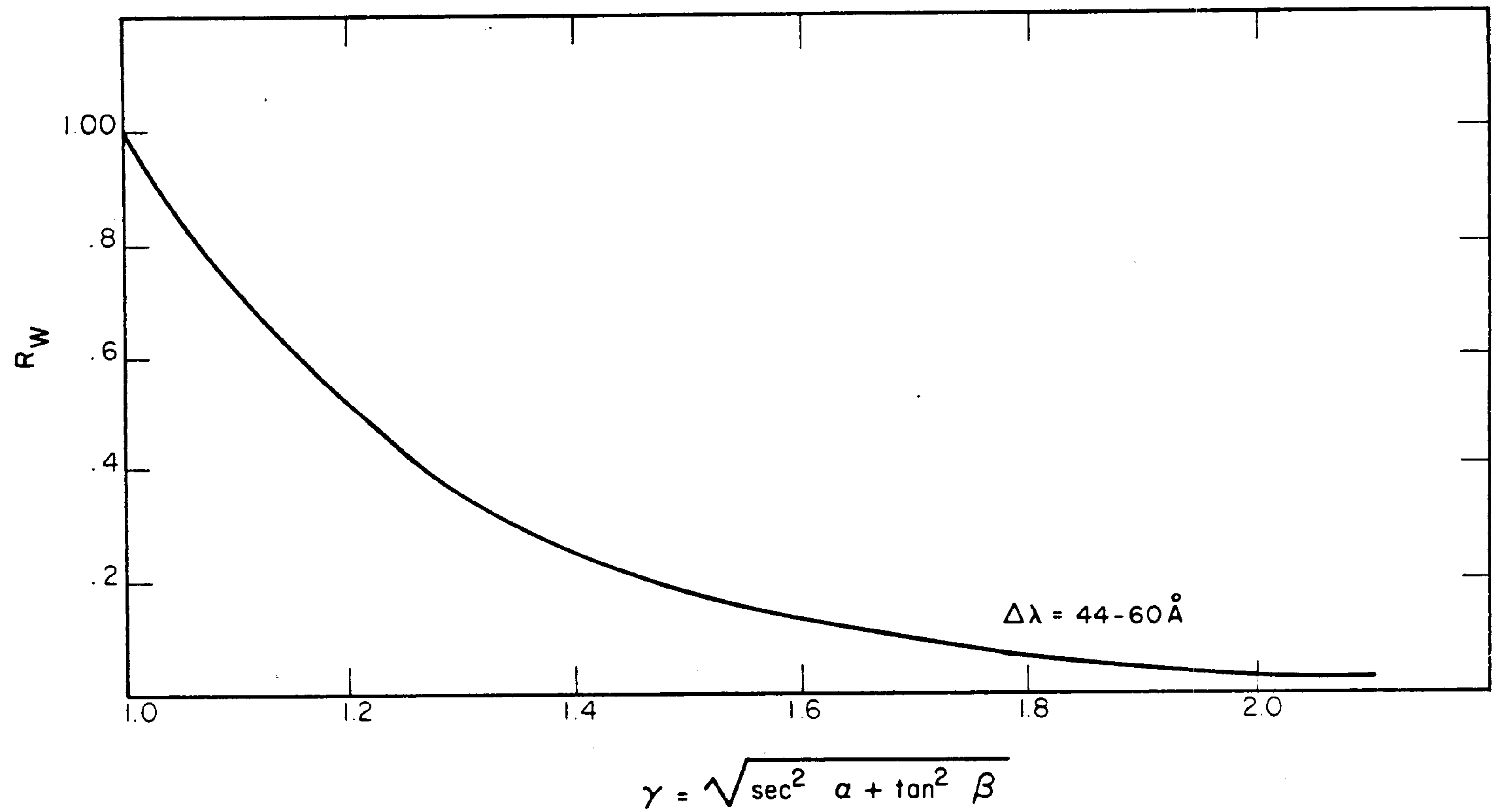
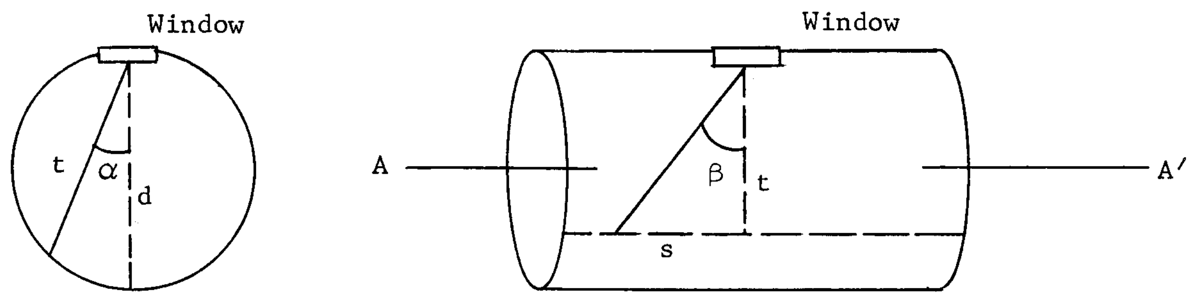


Figure 6. R_W as a function of γ.

5.3 EFFECT OF GAS

The Geiger counter may be considered approximately a cylinder with the window in the center of one wall as shown below.



The Geiger counter axis AA' is oriented in the plane of β, so the direction cosines of the radiation entering the chamber are designated α and β.

In the α plane, the path of the radiation within the gas is reduced to

$$t = d \cos \alpha$$

In the β plane, the path length will become

$$s = t \tan \beta$$

The total path is then given by

$$r = d \cos \alpha \text{ and } \beta$$

Since the efficiency of the gas is

$$1 - e^{-\mu r}$$

the ratio of efficiencies at oblique to normal incidence is given by

$$R_G = \frac{1 - e^{-\mu d \cos \alpha \sec \beta}}{1 - e^{-\mu d}}$$

For lack of experimental data, a conservative value of 13100 cm.^{2}/g. for μ/ρ will be used here. For one atmosphere of neon at room temperature,

$$\mu = (13100 \text{ cm.}^2/\text{g})(.90035 \times 10^{-3} \text{ g./cm.}^3) \frac{273}{293} = 10.99/\text{cm.}$$

With d = 2.2 cm.,

$$\mu d = 24.2,$$

so that R_G may be considered unity. At one half atmosphere pressure, however, the exponent given above becomes 12.1 at normal incidence, and therefore there is a slight contribution at high aspect angles. This is shown in Figure 7.

5.4 EFFECT OF EDGES

Since the counter has various edges and walls above and below the mylar window, some of the radiation will be obstructed at oblique incidence. This effect is difficult to calculate as a general function of angle and will, therefore, simply be designated by the term R_E. The counters that have a supporting window mesh have an additional contribution to R_E, which will become very large at high angles of incidence.

5.5 TOTAL EFFECT

The total effect of oblique incidence over normal incidence on the 44-60 Å radiation is therefore given by

$$R = R_F R_W R_G - R_E$$

The efficiency of the counter for these wavelengths is then given in terms of its efficiency at normal incidence by

$$\epsilon = R\epsilon_o$$

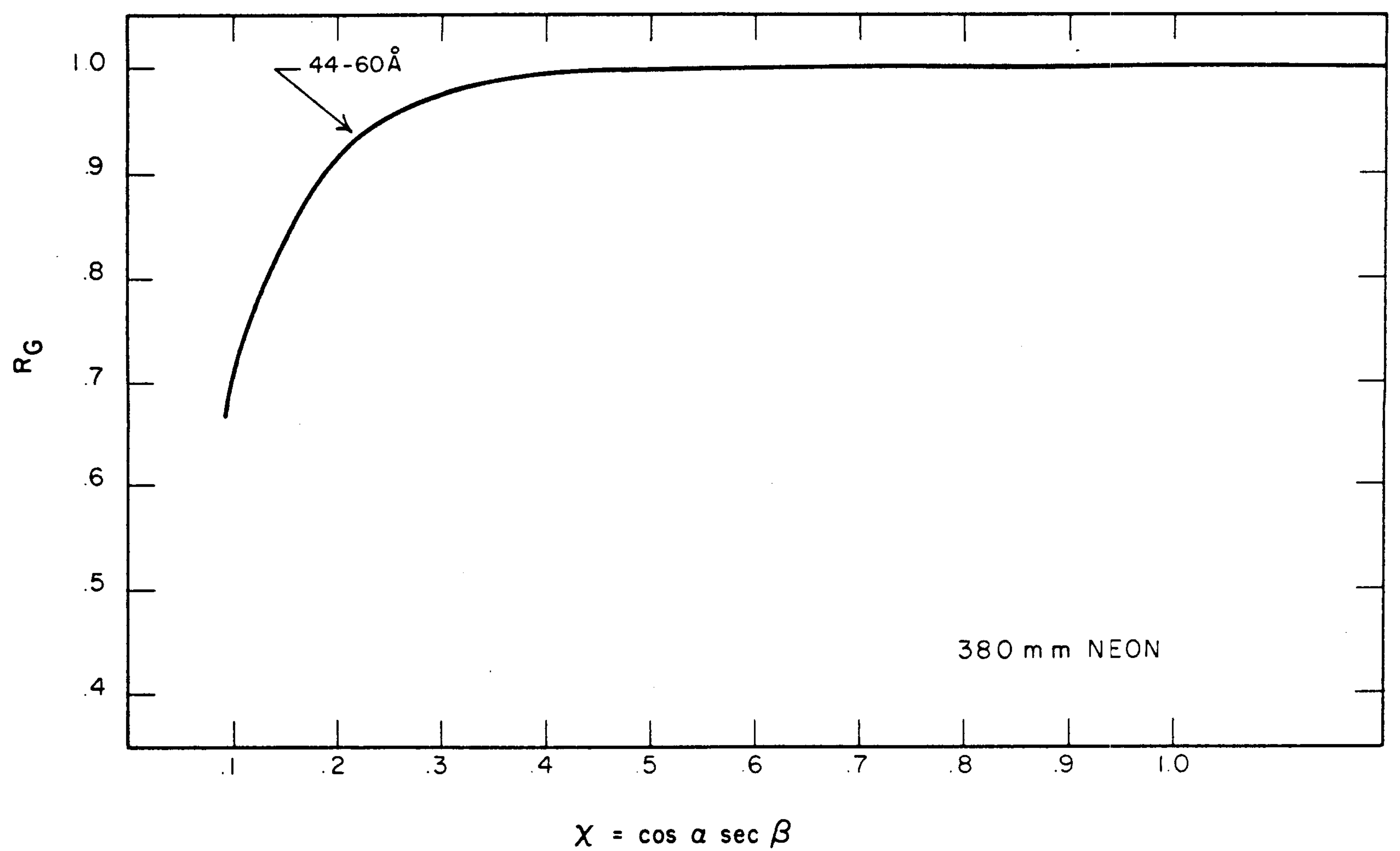


Figure 7. R_G as a function of χ.

This is plotted in Figure 8 for the case $R_E = 0$ for azimuth angles of 0^o and 18^o.

5.6 CONTAMINATION BY 2-20 Å RADIATION

As shown in Figure 5, the Geiger counter is also sensitive to 2-20 Å radiation. Since the solar flux in this spectral range is small, its effect is usually negligible. However, since the over-all efficiency of the counter is greater at the higher energy band pass than it is at 44-60 Å, at oblique incidence the relative effect of the 2-20 Å radiation might become enhanced. Except when the sun is very active, the flux below 12 Å can be considered negligible in comparison with the flux from 12 to 20 Å, where the counter efficiency at normal incidence is comparable to that in the 44-60 Å region. Therefore, if the flux from 2 to 12 Å can be neglected, there will not be an enhancement of the effect of the shorter wavelengths at oblique incidence. For purposes of comparison, the efficiency of the Geiger counter to radiation at 1.9 Å, 9.9 Å, and 44.6 Å as a function of aspect angle is shown in Figure 9.

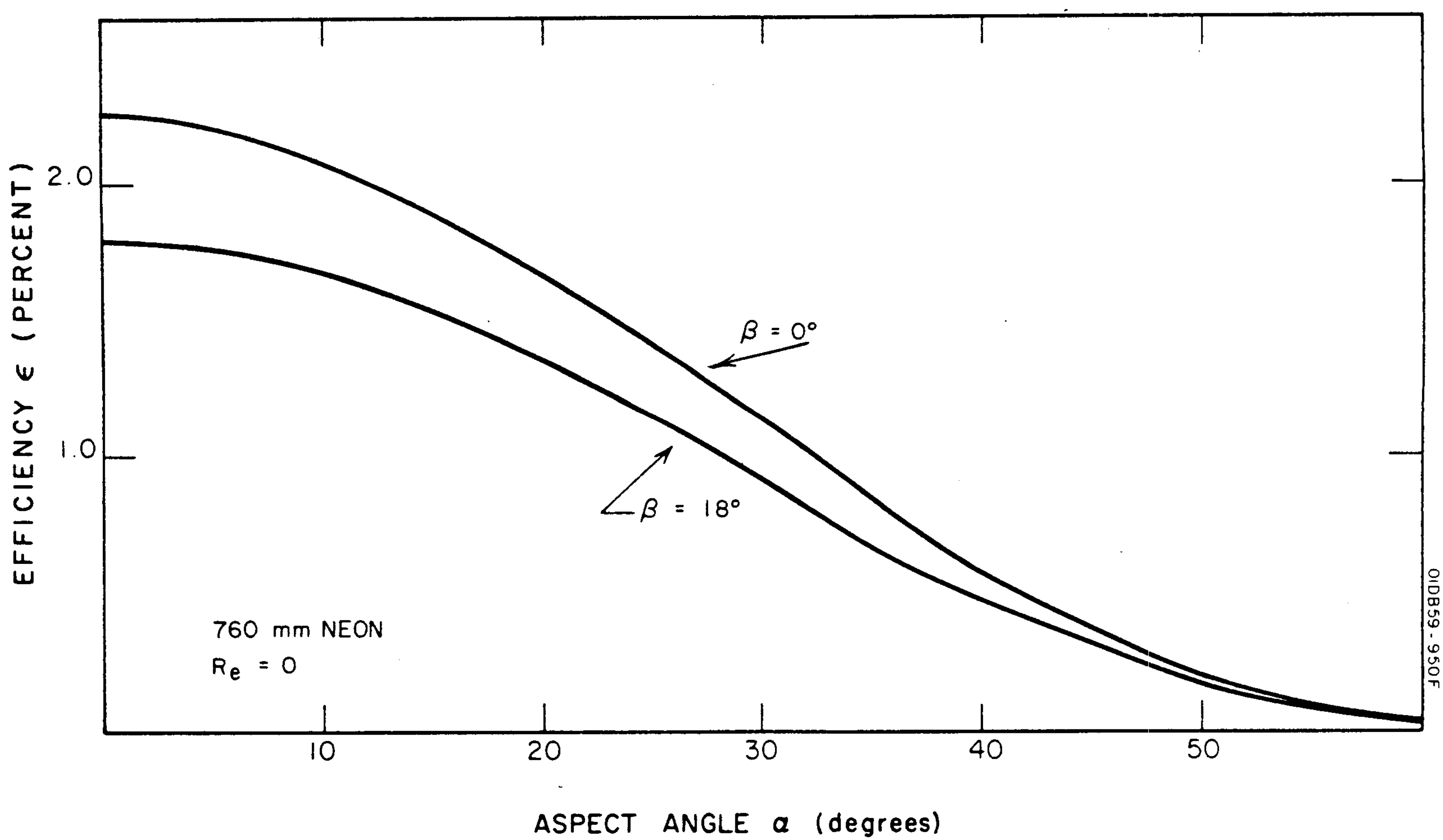


Figure 8. Efficiency and aspect dependence of Geiger counter in 44 - 60 Å interval for two azimuth angles.

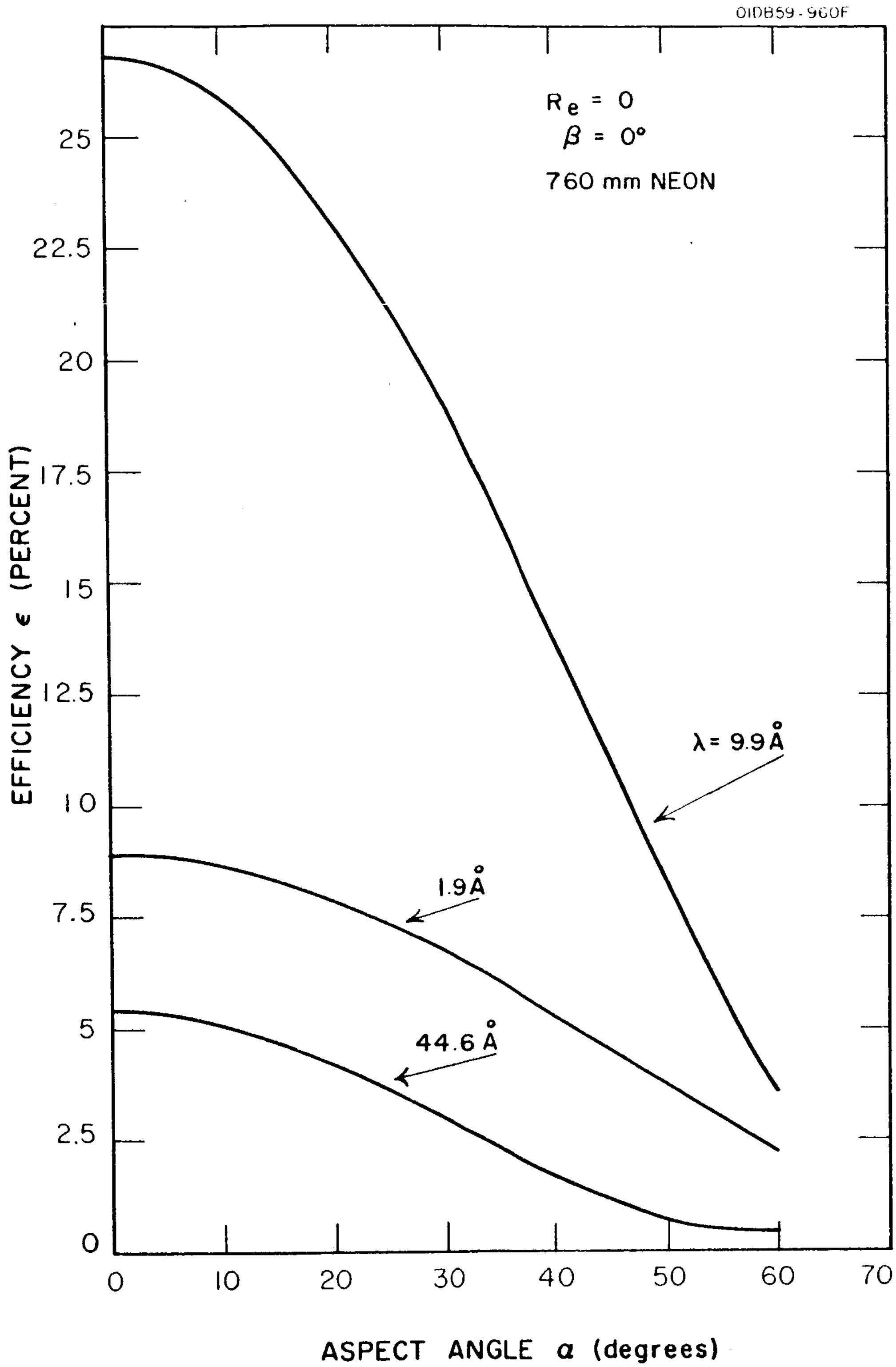
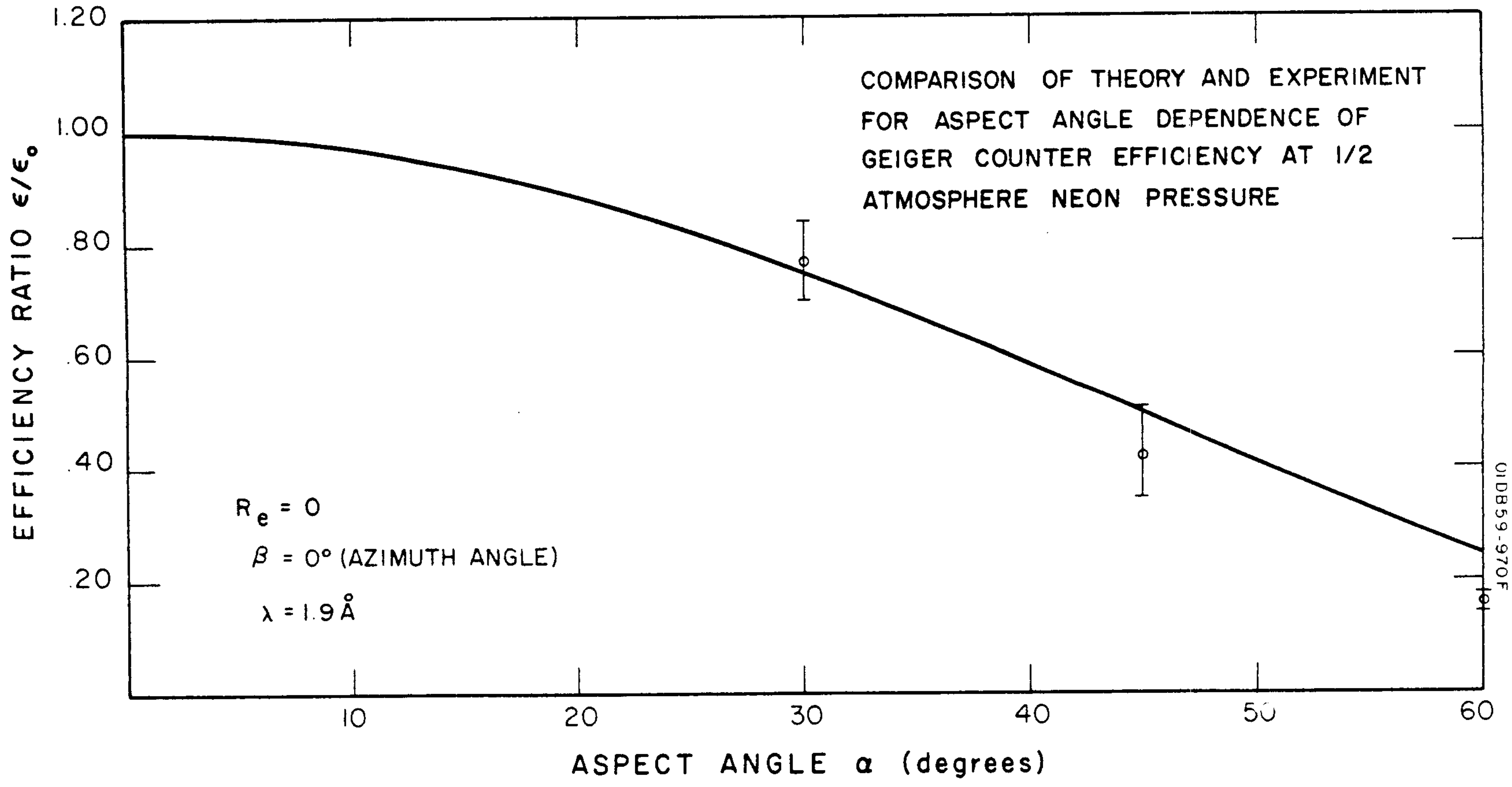


Figure 9. Efficiency and aspect dependence of Geiger counter at some specific wavelengths.

SECTION 6

MEASUREMENTS AND CONCLUSIONS

Due to the unavailability of an X-ray spectrograph in the 44 Å - 60 Å band, all measurments were made with an Iron 55 isotope. This isotope emits a monochromatic X-ray at 1.9 Å which is situated within the higher energy window of the mylar counter. The source strength is 5 millicuries making it possible to obtain relative efficiency measurements at various aspect angles. An absolute efficiency calibration of the counter for this wavelength is not possible since the flux from the source is not known accurately. All data was obtained in vacuum to minimize any errors due to absorption in air. Relative efficiency data, that is, the ratio of count rate at a particular angle to the normal incidence rate, was measured for 30°, 45° and 60°. This was done for counters filled to both one and one-half atmosphere neon pressures. A typical plot is shown in Figure 10 where a computed curve is superimposed for purposes of comparison. The discrepancy between theory and experiments is believed to be due to edge effects which are not included in the calculated values. This deviation becomes more significant for larger aspect angles.



COMPARISON OF THEORY AND EXPERIMENT
FOR ASPECT ANGLE DEPENDENCE OF
GEIGER COUNTER EFFICIENCY AT 1/2
ATMOSPHERE NEON PRESSURE
$R_e = 0$
$\beta = 0°$ (AZIMUTH ANGLE)
$\lambda = 1.9$ Å
EFFICIENCY RATIO ϵ/ϵ_o
1.20
1.00
.80
.60
.40
.20
10
20
30
40
50
60
ASPECT ANGLE α (degrees)
01DB59-970F

Figure 10.

To date, two counters have been tested in Nike-Apache flights during March and April at Wallops Island, Virginia. During the first flight, counter performance was excellent up to the time of release of the protective doors at 55 km. Coincident with the door release, the counter displayed a saturation count which is believed to be due to RF interference. In the second flight, additional precautions were taken to avoid any interference. These flight records indicate the counter operated successfully yielding useful data on the solar flux in the D and E region. Initial detection of 44 - 60Å radiation occurs at about 80 km altitude. Due to a large precession cone of the rocket, the aspect angle variation is considerable and appropriate corrections will be necessary to reduce this data to normal incident fluxes at various altitudes. The results indicate the adequacy of the present design and rocket integration, and point to the utility of this Geiger counter, particularly for the immediate objective of probing the ionosphere during a solar eclipse.

The authors wish to express their gratitude for the helpful suggestions of Dr. L.G. Smith. Thanks are also due to Mr. P.J. McKinnon and Mr. M. Wolpert for the design of the circuitry.